



# SPACE-BASED POSITIONING NAVIGATION & TIMING

NATIONAL EXECUTIVE COMMITTEE

## National PNT Systems Engineering Forum (NPEF)

### LightSquared Effects on GPS Test and Analysis Results

June 9, 2011

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# Overview



- **Background**
- **Test Methodology and Results**
- **Next Steps**



# Background



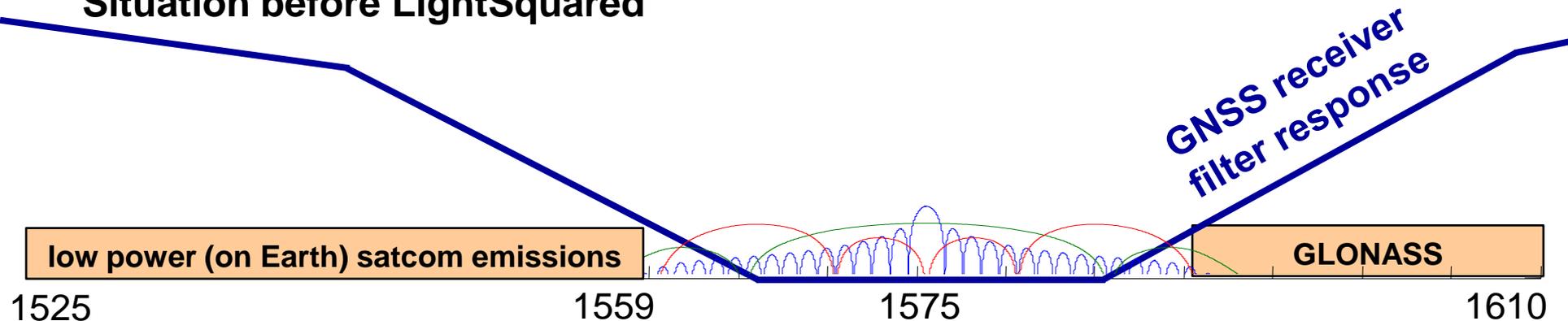
- **Perform “Assessment of LightSquared Terrestrial Broadband System Effects on GPS Receivers & GPS-dependent Applications”**
  - Evaluate and assess LightSquared’s planned deployment of a terrestrial network of Ancillary Terrestrial Component (ATC) base stations
  - Coordinate test efforts with FCC, LightSquared, NTIA and EXCOM Departments and Agencies
  - Assess potential mitigations for GPS receivers



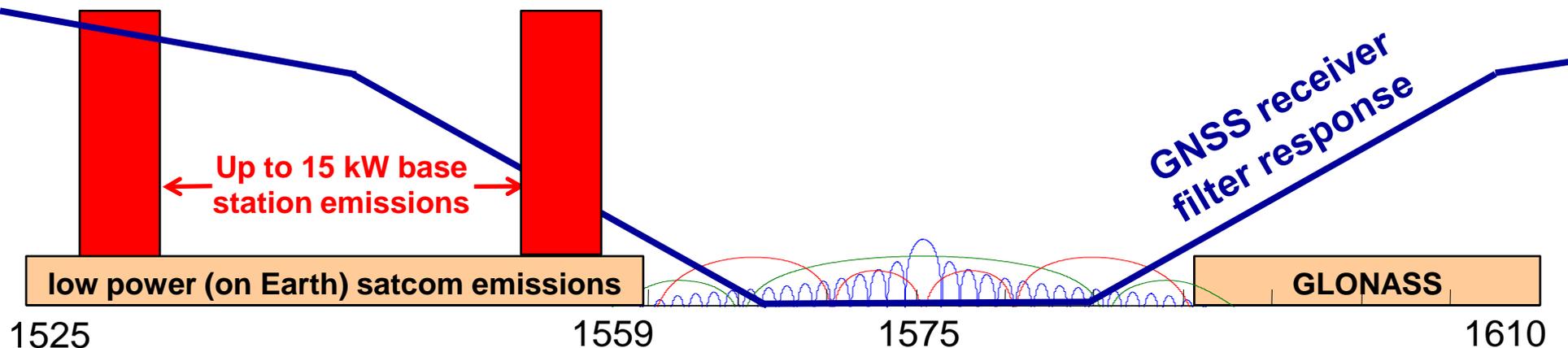
# Illustration of Concerns



## Situation before LightSquared



## Situation with LightSquared





# NPEF Test Methodology



- **Develop Comprehensive Test Plan**
  - Test approach, environment and receiver sets
  - Test hardware included LightSquared supplied filter
  - LightSquared Engineers examined and concurred with test setup
- **Test Methods Used**
  - Laboratory Conducted Emissions
  - Anechoic Chamber
  - Live Sky with single ATC



# Conducted Emissions Testing



- **Provided basis for NPEF, RTCA WG6, TWG aviation receiver assessments**
- **Test Approach**
  - Connect all signals directly to input of receiver filter/LNA (directly after GPS antenna element)
  - Power input stepped (1 dB steps) using variable attenuator
- **Emulate LightSquared signals using shaped noise**
  - 5 MHz bandwidth noise signal(s) centered at 1552.7 MHz (high band) and/or 1528.8 MHz (low band)
  - 10 MHz bandwidth noise signal(s) centered at 1550.2 MHz (high band) and/or 1531.0 MHz (low band)
  - Tests use two cascaded LightSquared RF filters at each channel



# Conducted Emissions Test Summary



- **Characterization tests performed on GNSS receivers**
  - Evaluated Phase 0, 1 and 2 signal configurations as well as 5 and 10 MHz Low channel signals
  - Used conducted, simulated signals in Zeta laboratory
    - System susceptibility and resultant standoff distances considered antenna effects (pattern, polarization, elevation, etc.)
- **Results indicate large variation in susceptibility to LightSquared signals**
  - All receivers adversely affected by Phase 0, 1, 2 signals to varying degrees (> 30 dB range in Phase 0 power for 1-dB C/No degradation)
  - 5 and 10 MHz Low signals caused minimal effects on the limited set of receivers that were tested
  - Conducted 1 dB C/No degradation and loss of tracking tests for seven receivers related to FAA infrastructure and aviation
  - SBAS word error rate tests conducted for two aviation receivers



# Anechoic Chamber & Live SkyTesting



- **DoD coordinated two tests to assess LightSquared impacts**
  - Chamber Test: April 4-7, 2011 – White Sands Missile Range, NM
  - Live Sky Test: April 14-17, 2011 – Holloman AFB, NM
  - Testing open to numerous external agencies
- **Examined all three phases of LSQ operations**
  - Phase 0: Single channel 5 MHz upper band
  - Phase 1: Dual channel 5 MHz (planned February 2012)
  - Phase 2: Dual channel 10 MHz (planned July 2013)
- **Test Limitations**
  - Not all GPS receivers/applications tested (e.g., timing, cell phones)
  - Limited to single LSQ transmit antenna (aggregate effects modeled)



# Chamber Testing Summary



- **Successfully completed 32 test events**
- **Results**
  - FAA – All receivers lost GPS solution
  - Survey receivers lost GPS solution
  - John Deere receivers lost solution
  - USCG – Coastal dGPS service impacted
  - NASA – All high precision receivers for sciences impacted
  - Garmin chipset in personal navigation devices lost GPS solution





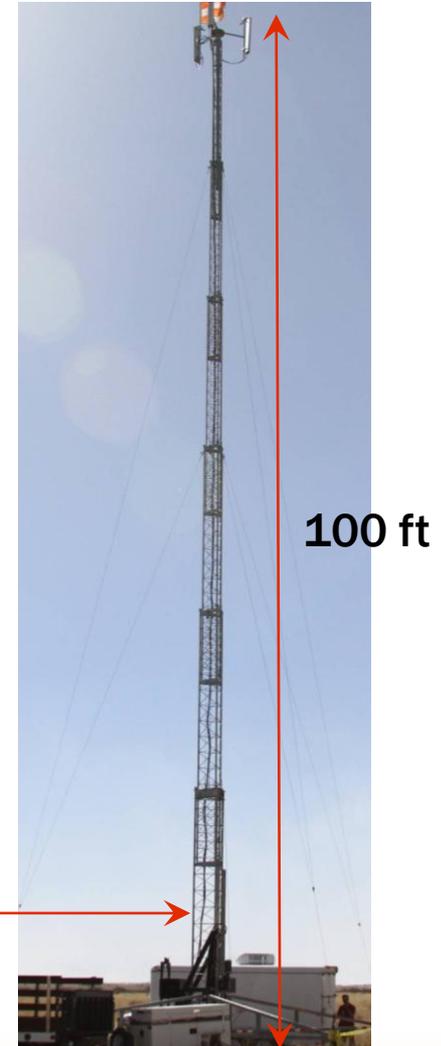
# LiveSky Testing



- Successfully completed **14** test events
- Test used LightSquared equipment
- Production transmitter set up and operated by LightSquared
  - **1<sup>st</sup>** operational use of LightSquared production unit; tested all modes



1,400 ft





# Live Sky Test Summary



- **First Responders**

- **State Police**

- Police cruiser lost GPS reception ~600 feet from tower
    - Police HQ could not locate cruiser on their tracking system

- **Ambulance**

- No PNT solution ~1,000 feet from tower
    - System presented false PNT data (9 mph while vehicle was stationary)

- **Fire Department**

- No PNT solution ~1,000 feet from tower
    - System reported last known vehicle position not near actual location

- **GM/OnStar**

- **Lost GPS on most receivers**
  - **Significant degradation of service**





# Distance (km) for Significant (1 dB) Degradation by Single LightSquared ATC



<b>Application</b>	<b>Phase 0</b>	<b>Phase 1</b>	<b>Phase 2</b>	<b>10 MHz Low</b>
<b>Aviation</b>	<b>24.3 – 1.1</b>	<b>27.2 – 1.2</b>	<b>19.3 – 0.9</b>	<b>&lt; 0.1</b>
<b>Maritime</b>	<b>NM</b>	<b>NM</b>	<b>NM</b>	<b>NM</b>
<b>High Precision (Survey, Agriculture, Science)</b>	<b>TBR – 0.5</b>	<b>TBR – 6.8</b>	<b>TBR – 3.8</b>	<b>TBR - &lt; 0.1</b>
<b>Timing</b>	<b>NM</b>	<b>10.8</b>	<b>NM</b>	<b>NM</b>
<b>Space</b>	<b>121.6</b>	<b>305.5 – 19.3</b>	<b>NM</b>	<b>NM</b>



# Distance (km) for Loss of Satellite Tracking as a Result of a Single LightSquared ATC



<b>Application</b>	<b>Phase 0</b>	<b>Phase 1</b>	<b>Phase 2</b>	<b>10 MHz Low</b>
<b>Aviation</b>	<b>10.8 – 0.4</b>	<b>12.2 – 0.5</b>	<b>8.6 – 0.3</b>	<b>&lt; 0.1</b>
<b>Maritime</b>	<b>0.6 – 0.2</b>	<b>1.6 – 0.4</b>	<b>1.0 – 0.3</b>	<b>&lt; 0.1</b>
<b>High Precision (Survey, Agriculture, Science)</b>	<b>2.2 – 0.2</b>	<b>7.7 – 2.1</b>	<b>6.1 – 1.7</b>	<b>0.4 - &lt; 0.1</b>
<b>Timing</b>	<b>NM</b>	<b>&lt; 0.1</b>	<b>NM</b>	<b>NM</b>
<b>Space</b>	<b>24.3</b>	<b>61.0 – 27.0</b>	<b>NM</b>	<b>NM</b>



# Planned ATC Density



**Typical distance planned between ATC transmitters:**

- **Dense urban environment**                      **0.4 - 0.8 km**
- **Urban environment**                              **1 - 2 km**
- **Suburban environment**                        **2 - 4 km**
- **Rural environment**                                **5 - 8 km**

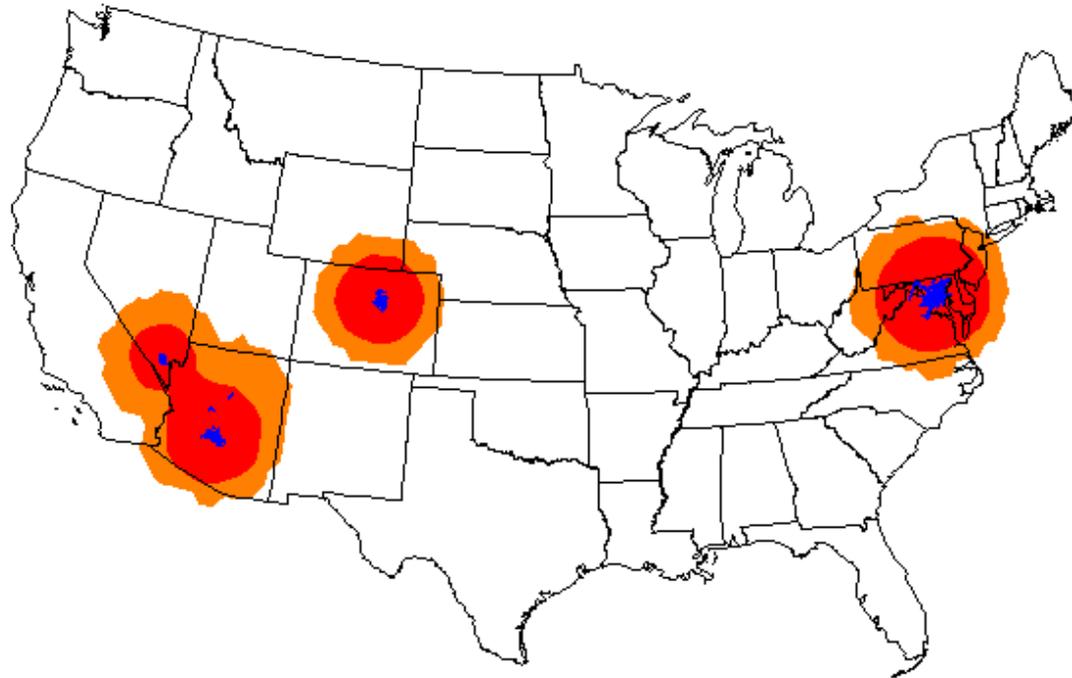


# Aviation Impact (Initial Deployment)



- FAA and International aviation standards GPS interference threshold limited (-86.4 dBm)

Effect on aircraft at 10,000 feet



LSQ emissions exceed aviation standard

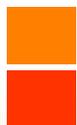
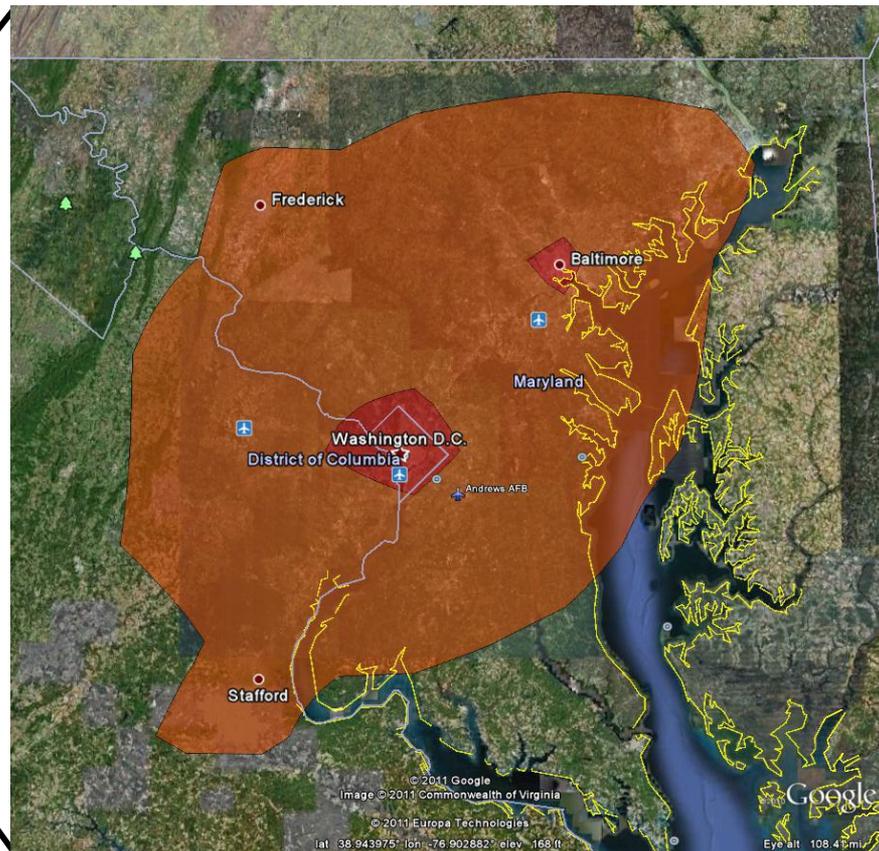
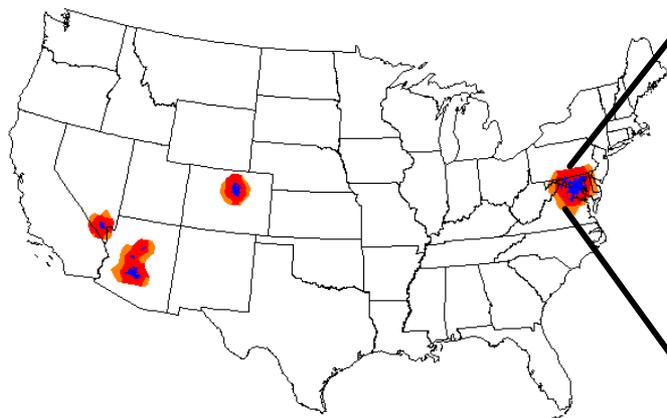
Significant measured degradation (common aviation receiver)



# Aviation Impact (Initial Deployment)



## Aircraft at 500'

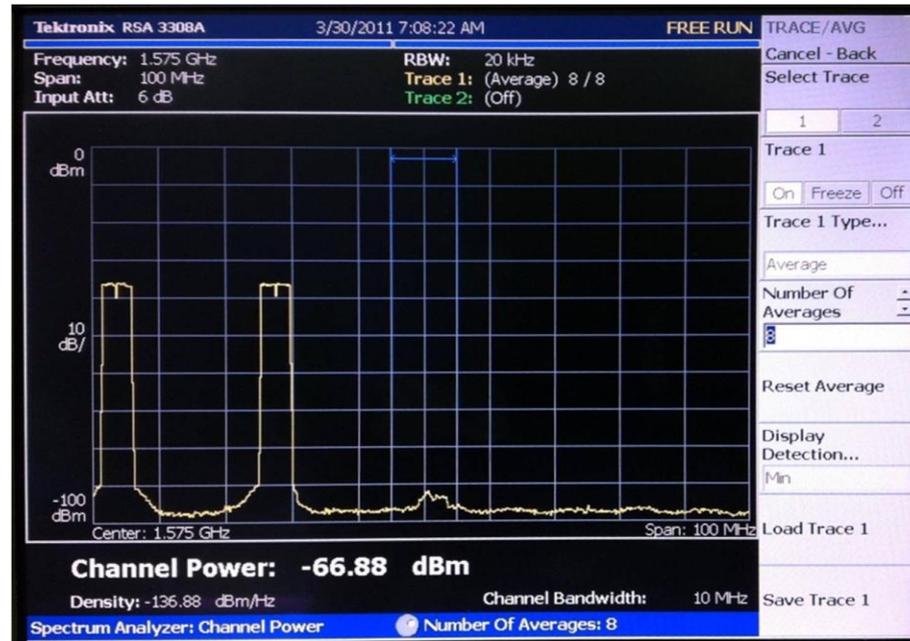


No Position Output – Aviation Receiver “A” (-47 dBm)

No Position Output – Aviation Receiver “B” (-37 dBm)



# NASA/JPL Test Results



- NASA Jet Propulsion Lab (JPL) results demonstrate significant interference effects to space receivers
- Next Generation space receivers inoperable at 300 Km
- Results revealed an intermodulation interference effect “in-band” to GPS
  - JPL results confirmed in anechoic chamber results



# Potential Mitigation Options



- **Relocate LightSquared transmission to different frequency band**
  - FCC/NTIA identify frequency band more suitable for high-power terrestrial transmission
- **GPS receivers include filters to reject/limit LightSquared transmission**
  - Considerable expense and lengthy transition period
  - Receiver performance may be affected
  - Additional filtering may be more beneficial for future receivers



# Potential Mitigation Options (continued)



- **Modifications to LightSquared antenna pattern and exclusion zones**
  - More base stations required to provide coverage
  - Increase to aggregate interference
- **LightSquared limit implementation to lower end of MSS L- band**
  - May affect ability to provide national broadband service
- **LightSquared (substantially) reduce base station transmitter power**
  - More base stations required to provide coverage



# Key Findings



- **All GPS receiver applications impacted by proposed LightSquared Network**
- **Simulation of fully deployed LightSquared network of ~40,000 base stations would:**
  - Degrade or result in loss of GPS function (ranging, position) at standoff distances ranging from few kilometers and extending to space operations
- **Out of band emissions due to close proximity to GPS Band**
  - Appear to be satisfactory
- **No universal mitigation approach identified**



# Next Steps



- **Additional Testing**
  - Assess LightSquared handset (or user terminal) transmissions (hardware not available for test)
  - Evaluate utility of single 5 or 10 MHz channel (1526.3 – 1531.3 MHz or 1526 – 1536 MHz) in lower MSS spectrum
  - Evaluate LightSquared effects on timing receivers
  - Conduct additional MOPS-based laboratory tests
    - Additional aviation receiver Word Error Rate tests
    - Pseudorange accuracy tests
  - Complete documentation and catalog test data
- **NPEF Report submitted 1 June**
  - Redacted version targeted for 8 June public release